Handling Branching Fractions Measured from Dalitz-Plot Analyses

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We propose a change in how we handle two-body branching fractions extracted from Dalitz-plot analyses for three-body decays of D mesons. Specifically, we recommend that for modes such as $D \to rc,\ r \to ab$ we not correct the D branching fraction for unseen decay modes of the resonance r. We instead recommend listing the D branching fraction for the entire decay chain $D \to rc,\ r \to ab$.[1] When interference effects in the three-body decay are significant, there is no reason to expect $\mathcal{B}(D \to rc,\ r \to ab)/\mathcal{B}(r \to ab)$ to be the same as $\mathcal{B}(D \to rc,\ r \to a'b')/\mathcal{B}(r \to a'b')$ since the interference effects depend on the particular set of intermediate two-body decays of the D that contribute to each three-body final state. Therefore, an important part of our recommendation is that we not average branching fractions for $D \to rc$ measured with different decay modes of the resonance r.

This proposal may affect the encoding of branching fractions for B mesons as well, for multibody final states with significant interference. However, the interference effects are not as important for B decays because the intermediate resonances are often much narrower in B decays (*e.g.,* D^* rather than K^* intermediate resonances) and the width of each resonance is a smaller

[1] In a Dalitz-plot analysis of $D \to abc$, the branching ratio for the intermediate submode j, $D \to rc,\ r \to ab$, is given as a "fit fraction" defined as the integral over the Dalitz plot (m^2_{ab} vs. m^2_{bc}) of a single amplitude squared divided by the integral over the Dalitz plot of the square of the coherent sum of all amplitudes: $\frac{\mathcal{B}_j(D\to rc,\ r\to ab)}{\mathcal{B}(D\to abc)} = \frac{\int |a_j e^{i\delta_j}\mathcal{M}_j|^2 dm^2_{ab} dm^2_{bc}}{\int |\Sigma_k a_k e^{i\delta_k}\mathcal{M}_k|^2 dm^2_{ab} dm^2_{bc}}$. The sum of fit fractions for all components j will, in general, not be unity due to interference. See the long form of the RPP2004 "Review of Charm Dalitz-Plot Analyses" by David Asner at hep-ex/0410014 for more details.

fraction of the kinematically allowed mass range in B decays, leading to a smaller fractional overlap area of resonances in the Dalitz plot.

We first describe in more detail how the branching fractions are currently handled, using a specific D^+ decay as an example. We also describe our proposed changes and how they will impact the branching fractions listed in the Review of Particle Physics.

Consider the three-body decay $D^+ \to K^-\pi^+\pi^+$. Dalitz plot analyses of this final state have been conducted by Mark III, E687, E691 and E791. Including only conventional resonances in the fit, all experiments find a large "nonresonant" fit fraction of over 90% and a poor fit to the data. E791 finds that the fit is improved very significantly if a low-mass s-wave $\overline{K}\pi$ resonance is included in the fit; this scalar resonance is then the dominant resonance and the nonresonant fit fraction is reduced from $\approx$ 90% to $\approx$ 10%. One of the intermediate two-body decays allowed in all the fits is $D^+ \to \overline{K}^*(892)^0\pi^+$. The fit fraction for this mode is given in the RPP2004 full listings under "OUR FIT" as $\frac{\Gamma(\overline{K}^*(892)^0\pi^+)}{\Gamma(K^-\pi^+\pi^+)} = 0.212 \pm 0.016$ with the footnote "Unseen decay modes of the $K^*(892)^0$ are included." We recommend that fit fractions be listed *without* correcting for unseen decay modes of the intermediate resonance (in this case $K^*(892)^0$) because this fit fraction is relevant to only one particular three-body final state (in this case $K^-\pi^+\pi^+$).

The decay $D^+ \to \overline{K}^*(892)^0\pi^+$ can also lead to the three-body final state $\overline{K}^0\pi^+\pi^0$. The dominant intermediate two-body submode is $\overline{K}^0\rho^+$. (Note that $K\rho$ is not an allowed submode for the $K^-\pi^+\pi^+$ final state.) The nonresonant fit fraction is not very significant. The fit fraction for $D^+ \to \overline{K}^*(892)^0\pi^+$ is given in the RPP2004 full listings under "OUR FIT" as $\frac{\Gamma(\overline{K}^*(892)^0\pi^+)}{\Gamma(\overline{K}^0\pi^+\pi^0)} = 0.20 \pm 0.06$ with the footnote "Unseen decay modes of the $K^*(892)^0$ are included." However, this fit value is dominated by the measured fit fraction for $D^+ \to \overline{K}^*(892)^0\pi^+$ from the final state $K^-\pi^+\pi^+$, described in the previous paragraph, under the assumption that

$$\frac{\mathcal{B}(D^+ \to \overline{K}^{*0}\pi^+,\ \overline{K}^{*0} \to \overline{K}^0\pi^0)}{\mathcal{B}(\overline{K}^{*0} \to \overline{K}^0\pi^0)} = \frac{\mathcal{B}(D^+ \to \overline{K}^{*0}\pi^+,\ \overline{K}^{*0} \to K^-\pi^+)}{\mathcal{B}(\overline{K}^{*0} \to K^-\pi^+)}.$$

This assumption is not valid because the submodes contributing to $\overline{K}^0\pi^+\pi^0$ and to $K^-\pi^+\pi^+$ are very different. We recommend that only direct measurements of the fit fraction for $D^+ \to \overline{K}^*(892)^0\pi^+$, $\overline{K}^*(892)^0 \to \overline{K}^0\pi^0$, measured directly with the final state $\overline{K}^0\pi^+\pi^0$, be included in the average and that unseen decay modes of the $\overline{K}^*(892)^0$ not be included in the branching fraction. The designation "OUR FIT" will then become "OUR AVERAGE".

In the Summary Tables, we already quote product branching fractions. For example, in the D^+ Summary Table under $K^-\pi^+\pi^+$, we list $\overline{K}^*(892)^0\pi^+ \times \mathcal{B}(\overline{K}^*(892)^0 \rightarrow K^-\pi^+)$. We should change this notation to $\overline{K}^*(892)^0\pi^+$, $\overline{K}^*(892)^0 \rightarrow K^-\pi^+$. We should not include measurements based on $D^+ \rightarrow \overline{K}^*(892)^0\pi^+$, $\overline{K}^*(892)^0 \rightarrow \overline{K}^0\pi^0$ in this average. Similar comments apply to the listings under $\overline{K}^0\pi^+\pi^0$.

Because we are recommending dropping constraints that are not valid due to interference effects, the central values for a number of branching fractions will change and the uncertainties will increase. Approximately 30 data blocks related to D decays to $K\pi\pi$, $K\overline{K}\pi$ and $\pi\pi\pi$ are affected. If we extend the recommendation to submodes leading to four-body final states (e.g., $D \rightarrow K^*\pi\pi$, $K^* \rightarrow K\pi$), then the number of affected data blocks more than doubles.